# DESIGN AND ASSESSMENT OF A LOW IMPACT DEVELOPMENT (LID) STORMWATER MANAGEMENT SYSTEM IN PUROK 4, PHASE 6, BARANGAY 178, CAMARIN, CALOOCAN CITY

A Research Project

Presented to the Faculty of Civil Engineering Division

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In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science in Civil Engineering

Major in Construction Engineering

and Management

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**RECOMMENDATION**

This is to certify that this research entitled " DESIGN AND ASSESSMENT OF A LOW IMPACT DEVELOPMENT (LID) STORMWATER MANAGEMENT SYSTEM IN PUROK 4, PHASE 6, BARANGAY 178, CAMARIN, CALOOCAN CITY", prepared and submitted by Jean C. Almoguerra, Happy Jane R. Guardian, Anna Marie L. Pamplona have been examined and approved for PRE ORAL DEFENSE.

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## CERTIFICATE OF ORIGINALITY

This certificate demonstrates the fact that the work was original to the researchers and that no other individual or group has written or published it before. Additionally, it declares that until proper acknowledgement has been given to them, no honors or recognition from other universities, colleges or higher education institutions were claimed here.

On top of that, we claim that our study's intellectual content is the product of our hard work, which required using both simple terminology and efficient presentation methods in addition to the group's original ideas.

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# CHAPTER 1

## The Problem and its Background

### Introduction

The City of Caloocan is classified as a Highly Urbanized City (HUC). It signifies its classification as one of the most populated and progressive cities in Metro Manila. Urbanization has led to the alteration of permeable lands to impermeable structures such as pavements, roads, sidewalks, parking lots, and buildings. While urbanization is profitable to the city's economy and infrastructure, it is associated with major challenges. Among these, flooding remains a major concern to the city, caused by poor drainage systems, ineffective practices of waste management, and the continuous alteration of natural land into urban development. North Caloocan often experiences flooding during heavy rainfall; one specific area is in Purok 4, Phase 6 of Barangay 178. The current creek in the area is incapable of accommodating large amounts of stormwater, resulting in inconvenience and property damage. These concerns not only interfere with daily activities but also threaten public health, infrastructure, and weaken the city's capability to face future challenges.

The changes in the land cover associated with high urbanization are responsible for the problems of water scarcity as well as increased flood risks faced by today's cities (Bradshaw et al., 2007, De Roo et al., 2003). Rainwater falls directly

on the ground in rural areas, where it is absorbed by the soil and can seep into the ground to recharge groundwater. However, rather than infiltrating the soil, rainwater in urbanized areas falls on impermeable surfaces like parking lots, walkways, and roadways. Urbanization reduces the amount of water that naturally infiltrates, increasing the risk of floods, which is often controlled by traditional stormwater management systems. Traditional management systems rely on underground pipes and concrete channels to carry runoff away from urban areas. Although these systems are efficient at transporting water, they do not utilize natural processes to manage water sustainably, involving the development of more flexible and environmentally friendly methods.

An effect of uncontrolled runoff of stormwater is due to frequent urban flooding, which can destroy infrastructure, lead people to involuntary resettlement, and interfere with necessary services. In highly populated areas like Caloocan, poor drainage systems increase the risk of flooding. These conditions raise public health concerns, such as exposure to contaminated floodwaters. By controlling the amount and quality of runoff the effective stormwater management helps reduce the risks. It decreases flood surges, minimizes erosion, protects water bodies, and encourages sustainable water use. Moreover, modern methods like Low Impact Development (LID) manage runoff and improve the urban environment. They incorporate green infrastructure that provides aesthetic appeal, recreational spaces, and ecological benefits.

The Low Impact Development (LID) concept began in 1990 in Prince George's County, Maryland, as an alternative to traditional stormwater best management practices installed at construction projects. It serves as an alternative to traditional stormwater management practices used in construction projects. Low-Impact Development (LID) provides a new way to incorporate natural water flow into urban design. Instead of viewing stormwater as waste, LID practices like permeable pavements, rain gardens, and rainwater harvesting aim to soak in, store, and treat runoff where it occurs. Globally, LID is recognized as a cost-effective strategy that helps control floods, improve water quality, recharge groundwater, and create greener urban areas.

This study focuses on the design and assessment of an LID-based stormwater management system for Purok 4, Phase 6 of Barangay 178, Camarin, Caloocan City. The research aims to create a practical design that fits the area's topography, land use, and hydrological conditions. It also assesses how well the system reduces runoff, mitigates flooding, and improves water quality. Additionally, the project aims to offer a sustainable model that can guide future drainage improvement programs in urban communities dealing with similar issues.

## Background of the Study

Urban flooding has become one of the most persistent environmental problems in highly populated cities like Caloocan. In Purok 4, Phase 6 of Barangay 178 Camarin Caloocan City, residents often deal with flooding after heavy rains, along with dirty water runoff that flows through the community and into the nearby creek. This problem occurs mainly due to the prevalence of paved surfaces, a poor drainage system and a lack of open green spaces to absorb the water. To help address this, the study will design a practical Low Impact Development (LID) Stormwater System that can effectively manage stormwater by mimicking the natural hydrological process. Proposed solutions include the use of rain gardens, permeable pavements, bioswales, and household rainwater collection tanks.

**Theoretical Framework**

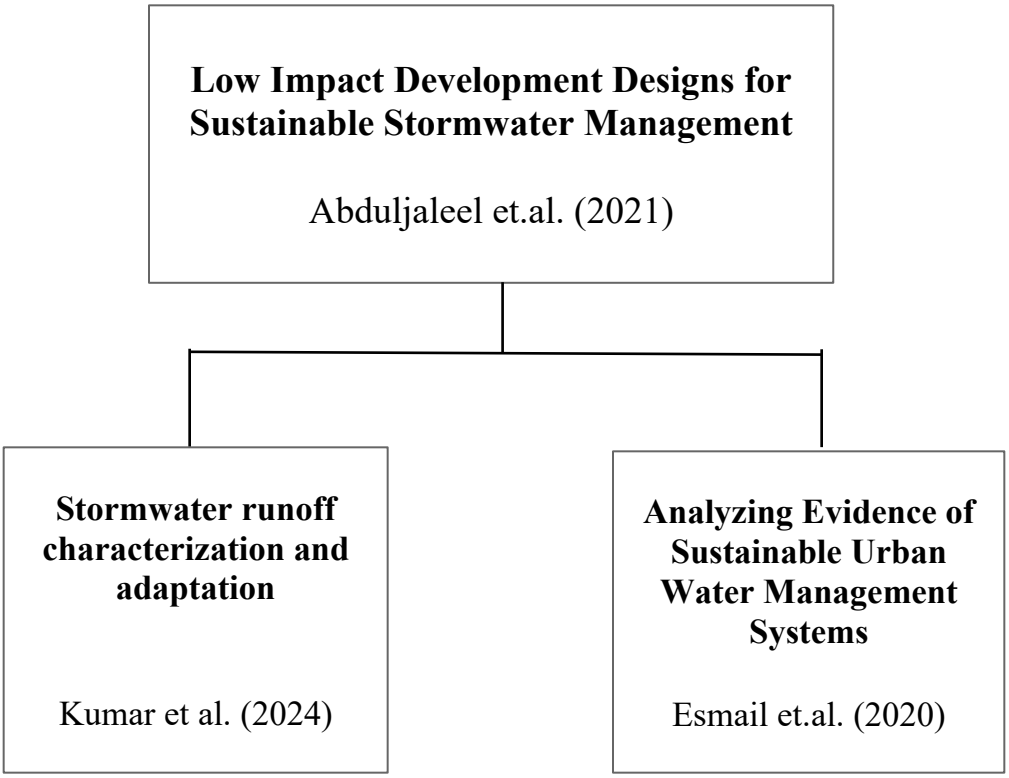
Low Impact Development Designs for Sustainable Stormwater Management
Abduljaleel et.al. (2021)
Stormwater runoff characterization and adaptation
Kumar et al. (2024)
Analyzing Evidence of Sustainable Urban Water Management Systems
Esmail et.al. (2020)

***Figure 1****: The theoretical framework outlines relevant theoretical perspectives from various research.*

The presented theories establish a coherent basis for the study by linking the principles of sustainable stormwater management, runoff characterization, and urban water system analysis. They provide essential guidance in formulating LID designs that are both technically sound and environmentally responsive to the conditions in Purok 4, Phase 6, Barangay 178, Camarin, Caloocan City.

**Conceptual Framework**

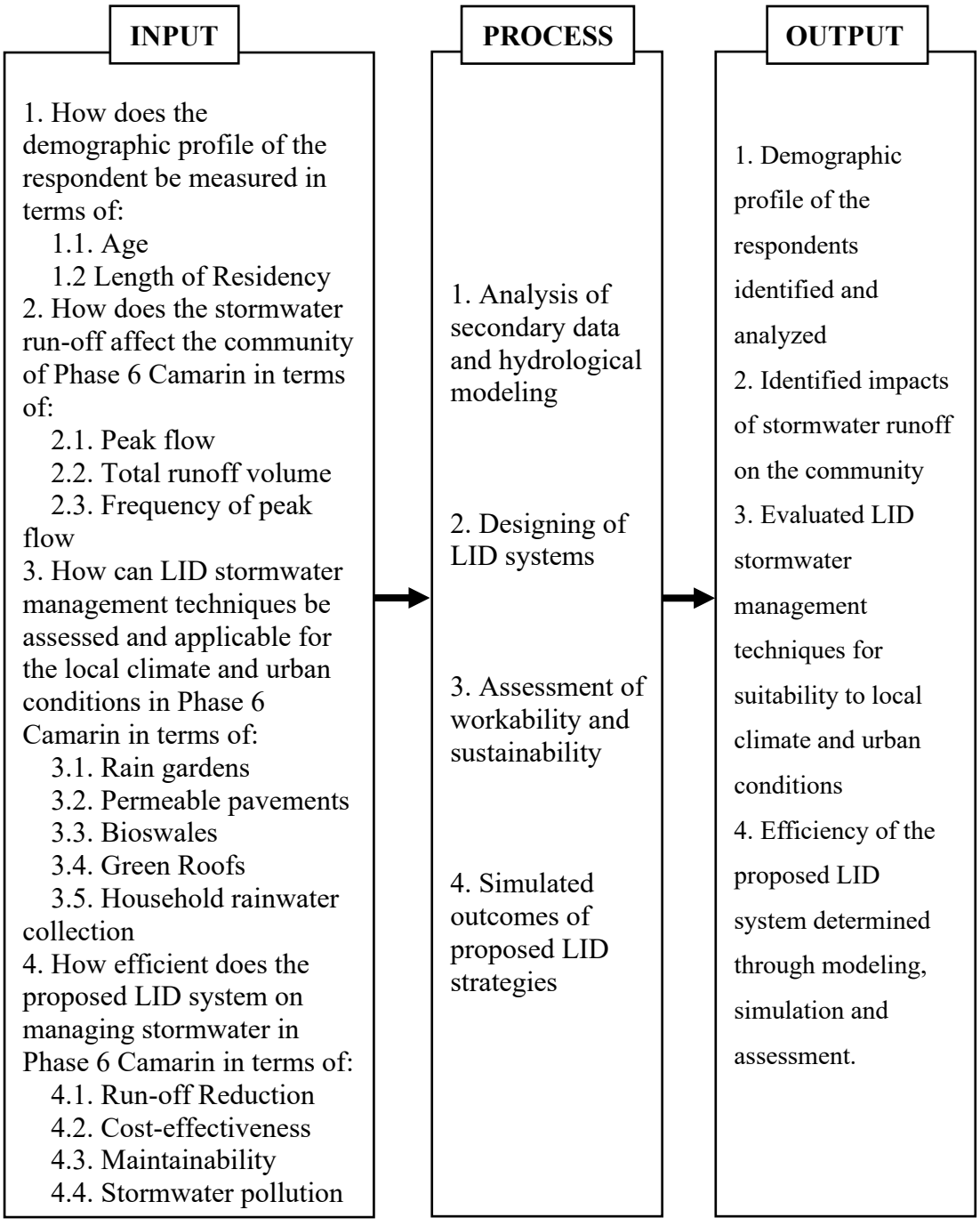
INPUT
1. How does the demographic profile of the respondent be measured in terms of:
1.1. Age
1.2 Length of Residency
2. How does the stormwater run-off affect the community of Phase 6 Camarin in terms of:
2.1. Peak flow
2.2. Total runoff volume
2.3. Frequency of peak flow
3. How can LID stormwater management techniques be assessed and applicable for the local climate and urban conditions in Phase 6 Camarin in terms of:
3.1. Rain gardens
3.2. Permeable pavements
3.3. Bioswales
3.4. Green Roofs
3.5. Household rainwater collection
4. How efficient does the proposed LID system on managing stormwater in Phase 6 Camarin in terms of:
4.1. Run-off Reduction
4.2. Cost-effectiveness
4.3. Maintainability
4.4. Stormwater pollution
PROCESS
1. Analysis of secondary data and hydrological modeling
2. Designing of LID systems
3. Assessment of workability and sustainability
4. Simulated outcomes of proposed LID strategies
OUTPUT
1. Demographic profile of the respondents identified and analyzed
2. Identified impacts of stormwater runoff on the community
3. Evaluated LID stormwater management techniques for suitability to local climate and urban conditions
4. Efficiency of the proposed LID system determined through modeling, simulation and assessment.

***Figure 2:*** *Research Paradigm*

**Statement of the Problem**

This project aims to design and assess a low-impact development (LID) stormwater management system for Purok 4, Phase 6, Camarin, Caloocan. Furthermore, this project seeks the answers to these specific questions:

1. How does the demographic profile of the respondent be measured in terms of:

    1.1. Age

    1.2. Length of Residency

2. How does the stormwater runoff affect the community of Phase 6 Camarin in terms of:

    2.1. Peak flow

    2.2. Total runoff volume

    2.3. Frequency of peak flow

3. How can LID stormwater management techniques be assessed and applicable for the local climate and urban conditions in Phase 6 Camarin in terms of:

    3.1. Rain gardens

    3.2. Permeable pavements

    3.3. Bioswales

    3.4. Green roofs

3.5 Household rainwater collection

4. How efficient does the proposed LID system on managing stormwater in Phase 6 Camarin in terms of:

4.1. Run-off Reduction

4.2. Cost-effectiveness

4.3. Maintainability

4.4. Stormwater pollution

**Objectives of the Study**

**General Objective:**

To design and assess the sustainable stormwater management system by applying Low-Impact Development (LID) strategies in Purok 4, Phase 6, Camarin, Caloocan.

**Specific Objective:**

1. To assess the current conditions in Purok 4, Phase 6, Camarin by examining factors such as topography and drainage patterns.
2. To develop a design plan for a sustainable stormwater management system utilizing Low-Impact Development (LID) strategies.

3. To determine suitable LID strategies for implementation in the area.
4. To simulate the effectiveness of the proposed LID strategies in improving stormwater management and reducing flood risks in the area.

## Hypothesis

**$H_a$**. The designed Low Impact Development (LID) stormwater management system will have significant effect on reducing surface runoff, improving the drainage system, or minimizing flooding in the study area.

**$H_o$**. The designed Low Impact Development (LID) stormwater management system will have no significant effect on reducing surface runoff, improving the drainage system, or minimizing flooding in the study area.

## Significance of the Study

This study could be significant because it addresses environmental challenges and can contribute to sustainable urban planning and development. The results of this study are expected to benefit the following:

**For Future Researchers** - Future researchers can use this study as a valuable reference for their future studies related to Low Impact Development and sustainable stormwater management. It provides data, methodologies and design assessments that can guide them in improving or adapting LID systems to different local conditions.

**For Local Community** – This study will benefit the residents of Purok 4, Phase 6, Camarin, by promoting improved stormwater management, minimizing flooding, enhancing water quality, and supporting better public health and safety. It also aims to promote community participation and awareness of sustainable practices.

**For the Government** – This study will provide the government with valuable insights and data to support the development of more programs for stormwater management and flood mitigation that incorporates Low Impact Development practices. By presenting sustainable and cost-efficient Low Impact Development (LID) designs, this study can serve as a model for future infrastructure planning that prioritizes environmental protection and community resilience.

## Scope and Limitation

This study focuses on Purok 4, Phase 6 of Barangay 178, Camarin, Caloocan City, with the objectives of addressing the flooding problem and stormwater management in the area. It covers the design and assessment of selected Low Impact Development (LID) practices, including rain gardens, permeable pavements, bioswales, green roofs, and household rainwater collection tanks.

The study is limited to the use of hydrological analysis and design simulation tool, analysis of secondary data, and community consultation. There are also limitations that can affect the design of the proposed LID strategies, such as time and

budget constraints, and the findings will be based solely on simulated outcomes and available information. Long-term monitoring and evaluation of the system's performance are not included in the scope of this research.

**Definition of Terms**

For better clarification and understanding, the important terms used in this study have been defined. The following terms are:

**Bioswales** – refers to landscape features that use soil and vegetation to slow down, collect, and filter stormwater runoff before it enters drainage systems or natural water bodies.

**Drainage System** - refers to the designed network of structures, pipes, and channels used to collect, transport, and dispose of excess surface or subsurface water.

**Hydrological Process** - refers to the natural movement of water.

**Impermeable Surfaces** - are surfaces that do not allow water to pass through, causing more runoff.

**Low-Impact Development (LID)** - is an approach to land development and stormwater management that aims to mimic the natural water cycle as closely as possible.

**Permeable Pavements** - are pavements made of materials that allow rainwater to pass through into the ground.

**Rain Gardens** - are shallow planted areas that collect and absorb rainwater runoff from roofs, driveways, and streets.

**Rainwater Harvesting** - refers to the collection and storage of rainwater, usually from rooftops, for later use.

**Runoff** – this refers to rainwater or melted snow that flows over the land instead of soaking into the ground.

**Stormwater Management** - all methods and systems used to control the quantity and quality of stormwater runoff.

**Stormwater Runoff** - is generated when precipitation from rain or melting snow flows over land or impermeable surfaces without infiltrating into the soil, often carrying pollutants and contributing to flooding and erosion.

**Sustainable Development** - this is a development that meets present needs without harming the ability of future generations to meet their own needs.

**Topography** - refers to the physical features of land such as its slope, shape, and elevation, which affect how water flows in an area.

**Urbanization** - the transformation of unoccupied or sparsely occupied land into densely occupied cities.

# CHAPTER 2

## Review of Related Literature and Studies

This chapter presents the related literature and studies gathered through a thorough search conducted by the researchers from both foreign and local sources. It also presents the synthesis of the review of related literature and studies, emphasizing their significance to the present research.

### Foreign Literature

Based on the article of Balaian, et al. (2024), entitled "How Urban Forms Impacts Flooding" flooding remains a common problem in urbanized areas. Due to the combined effects of urbanization and climate change it is evident that there is an increase of flooding worldwide. This problem emphasizes the importance of developing an effective drainage system and urban planning. In the past, to accommodate urban development, urban drainage systems have been adapted. Several researchers have addressed the evolution of drainage and flood management approaches, and readers are encouraged to refer to these studies for more detailed review.

Additionally, the article emphasizes that the characteristics of urban form, such as building plan, ground slope, and urban porosity, have a significant impact on the concentration and intensity of flooding. Having knowledge and understanding of these, the development of appropriate concepts and approaches for localized flood risk

forecasting has been able to be developed by the researchers and planners. Given this information, urban planning has the potential to overcome traditional drainage systems and develop innovative, flood-resilient designs that minimize risks while promoting sustainable development.

This literature has focused on the immediate need to address flooding through appropriate and sustainable urban planning. While the cities continue to develop despite the challenges of climate change, incorporating scientific knowledge of urban form with innovative flood management strategies becomes imperative. Establishing urban resilience to flooding not only works in favor of the protection of the environment but also a crucial part of securing human wellbeing and promoting sustainable urban development.

According to La Loggia, et al. (2020) in article Floodability: A New Paradigm for Designing Urban Drainage and Achieving Sustainable Urban Growth, highlights that rather than withstanding floods, cities are supposed to adapt through the inclusion of drainage systems that identify and manage flood risks. This paradigm alters the attention from the traditional flood risk management approach towards integration with water systems, and understanding floods as natural phenomena rather than only as threats. In this way, cities are able to strengthen resilience, minimize flood risk exposure, and support long-term sustainability. The article highlights the importance of innovative and resilient planning methods in an aim to mitigate the negative effects of flooding while avoiding poorly planned urban development.

Therefore, urban drainage system planning necessitates a shift in paradigm to emphasize the integrated hazard management through localized scale planning and the development of innovative flood risk management techniques, leading to the development of resilient and floodable cities. Analyzing urban areas flood risk exposure is important, considering all flood-prone areas at the local scale. This method should utilize geospatial and technologies to decrease inconsistencies, improve analytical accuracy, and address gaps emerging from this risk exposure through an integrated approach.

This article has addressed flood resilience through analyzing either society or infrastructure without referring to the discussion on how social and technical aspects influence each other. The concept of floodability highlighted in this paper seeks to combine these two aspects, hence demonstrating how a region's susceptibility to flooding can establish new development. Through the integration of urban planning, technical infrastructure, and social interaction, floodability provides a comprehensive implementation to risk management, allowing for strategies that reduce vulnerabilities and promote flood-risk resiliency of a community.

According to Miguez, et al. (2012) in the article entitled “New urban developments: flood control and LID a sustainable approach for urban drainage systems”, creating a sustainable city is an important and integrated challenge, as cities consist of interconnected systems such as housing, urban infrastructure systems, and open spaces. Within this interconnected system a key system is urban drainage, since failure of this system can cause floods that affect life in the city, destroy infrastructure,

specifically the houses, affect transportation, compromise public health, harm the economy, and adversely impact the environment. Urban flooding has become one of the major concerns that a city faces, with losses on the economy increasing over recent years.

Furthermore, development of urban areas and urban drainage are significantly connected: urban form influences drainage patterns, increases runoff, and establishes more rapid, higher flow peaks, which intensifies flooding in developed areas. Traditional drainage systems, such as canalization or channeling, focus on mitigating the effects of increased flows rather than mitigating which causes the flooding. Whereas sustainable approaches, such as Low Impact Development (LID), with a purpose to restore natural conditions through infiltration, retention, and extended flow paths, minimizing changes to hydrology. This study discussed these approaches in a pilot area in Guaratiba, Rio de Janeiro, comparing a traditional drainage system with an LID-based design at both plot and catchment scales. The analysis considers two designed rainfall events to assess the performance at plot- and basin-scale levels.

This relevant literature evaluated a drainage approach using the LID approach to establish an economically effective local drainage system at the plot level while enhancing basin wide drainage efficiency. By integrating urban planning with hydrological management, this approach can improve urban resilience to flooding, providing a more effective and greener alternative to traditional drainage systems.

Based on the article of Eckart, et al. (2017) entitled “Performance and implementation of low impact development” Urban stormwater management (SWM)

is a crucial component of sustainable urban development, with significant ecological, economic, and social impact. Abrupt urbanization and climate change have increased impervious surfaces and runoff, surpassing the design capacity of a traditional drainage system. Traditional drainage systems, like gutters, particularly aim to channel water quickly but frequently intensify flooding, lessen infiltration, and alter natural water cycle. Thus, the need for sustainable approaches that manage the effects of urbanization and climate change have increased.

Moreover, Low Impact Development (LID) has been developed as a sustainable stormwater management strategy engineered to imitate natural water cycles and mitigate challenges on urban drainage systems. LID strategies, such as green roofs , rain gardens, and permeable pavements, highlight infiltration, evapotranspiration, and water quality enhancements. This approach can be implemented both as new developments and modifying in highly urbanized areas. LID is known worldwide, classified with several terms however all share the goal of incorporating natural water cycles into urban drainage planning. Green infrastructure, an important aspect of LID, also provides further advantages, including improved efficiency in energy, heat reduction to urban areas, enhanced aesthetics, and social and ecological gains. The literature indicated that integrating LID with traditional drainage often leads to the most effective outcomes.

Therefore, the reviewed literature emphasizes the efficiency of LID practices in addressing challenges to urban stormwater, lessening the flood risks, and adapting to climate change. LID strategy provides multiple benefits through improved water

management, enhancing quality of water, and enhancing urban quality of life and environmental well-being. Present research highlights optimization, modelling, and monitoring of LID strategies to affected entities in sustainable urban planning. In general, LID provides a significant approach for the integration of climate change and urban development into resilient, low-impact urban drainage systems.

According to Nethmini, et al. (2024), on the article entitled “Regenerative Stormwater Management: a Conceptual Framework for Bluegreen Infrastructure”, with enhancement of urban areas and infrastructure it has escalated challenges associated to stormwater, resulting in increased runoff, recurring flooding, and economical and environmental damages. Traditional drainage systems, which highlight rapid channeling of water, are progressively failing to address and manage pollution control effectively, ecological balance, and long-term sustainability. In this article, Blue-Green Infrastructure (BGI) has been developed as an effective and sustainable approach, integrating natural and engineered systems to imitate the hydrological process. Through this literature review, it analyzes factors to the environment and social of BGI in stormwater management to develop an effective basis for creating a conceptual framework that enhances its implementation in urban areas.

Nethmini, et al. (2024) present that BGI signifies an ecosystem-based approach that integrates green and blue infrastructures to regulate stormwater through infiltration, storage, detention, and removal of pollutants. An example of BGI are rain gardens, bioswales, green roofs, and retention basins, that all serve a multi-purpose

like flood control, conversion of biodiversity, and purification of water. Aside from hydrological benefits, BGI also strengthens the livability of urban areas through improving quality of air, nurturing biodiversity, lessening heat urban stresses, and developing recreational spaces. However, although BGI has established benefits, there is limited implementation of it. Studies present challenges such as gaps in technical knowledge, institutional limitations, uncertain regulatory frameworks, and financial constraint. Additionally, lack of standardized guidelines and assessment frameworks reduces confidence in long-term performance of BGI compared to traditional drainage systems. Addressing these challenges requires enhanced community involvement, collaborative governance, integrated policy framework, mechanisms for sharing knowledge.

Therefore, the literature presents that while advantages to the environment and society of BGI are clearly evidenced, practical implementation is still hindered by challenges to the institutional, social, and political. A systematic framework is thus needed to guide stakeholders in utilizing BGI for stormwater management sustainability. An effective framework should integrate efficiency with institutional governance, awareness, and sustainable maintenance for long-term system maintenance. Through synthesizing existing studies, this research aims to address gaps in both theory and practice by supporting the strategic integration of Blue-Green Infrastructure (BGI) to enhance urban resilience, promote sustainability, and deliver multifunctional benefits in stormwater management.

**Local Literature**

Based on the article of Algallar et al. (2024) entitled "Managing Urban Water Resources: A Review of Challenges, Techniques, and Sustainability Strategies" published in Engineering, Technology & Applied Science Research (ETASR), it addresses the growing pressures on urban water systems from rapid urbanization, climate change, and population growth, which strain supply, quality, and infrastructure resilience. The review categorizes key challenges including water scarcity, pollution, aging infrastructure, and fragmented governance. It further evaluates modern techniques employed to improve urban water management such as integrated water resources management (IWRM), smart water technologies, distributed infrastructure like green infrastructure and low impact development (LID), and demand management strategies. Emphasis is placed on the importance of combining traditional engineering solutions with nature-based solutions to enhance sustainability.

Moreover, sustainability strategies outlined in the literature emphasize adaptive management frameworks incorporating stakeholder engagement, data-driven decision-making and policies promoting water conservation and reuse. The review advocates for cross-sector collaboration, resilience-building to adapt to climate variability and extremes, and investment in innovative infrastructure to achieve sustainable urban water futures. This article serves as a valuable resource summarizing the current state of urban water management research, practical techniques and forward-looking strategies that can be used as a guide by policymakers, planners and water resource professionals to address complex urban water challenges holistically

and sustainably.

According to the article of Cole (2022), titled "Solving the country's flooding problem through low-impact development solutions" published by The LaSallian, highlights the growing flood risk in the Philippines due to frequent tropical storms, urbanization and climate change. Ranked second worldwide for annual tropical cyclones, the country faces increasing damage to communities from storm surges and flash floods worsened by rapid urban development that replaces natural permeable surfaces with impermeable roads and buildings.

The article presents Low Impact Development (LID), a cutting-edge, environmentally approach of managing urban water resources. Restoring permeability in urban settings is the main goal of LID in order to promote groundwater recharge, lessen floods, and decrease stormwater runoff. Green roofs, which lower runoff and enhance the urban microclimate, rain gardens and bioretention cells, which collect and purify rainfall, and permeable pavements, which permit infiltration beneath sidewalks and roadways, are a few examples of LID practices that were covered.

Further, the article also comes to the conclusion that LID is a viable, sustainable substitute for traditional flood management, offering chances to modify and improve designs for the tropical climate and flood-prone regions of the Philippines. In order to fully utilize LID's advantages for a more resilient, environmentally friendly flood prevention future in the Philippines, it promotes greater research, policy acceptance, and public awareness.

Orale et.al. (2025) offers a policy-oriented framework that promotes the

integration of Low Impact Development (LID) principles into urban planning and building regulations in the Philippines. In his study, “Harmonized Low Impact Development (LID)-based building and urban design policies for the Philippines”, he emphasizes the urgency of adopting sustainable stormwater management systems in response to the country’s high vulnerability to climate-induced flooding and rapid urbanization. Drawing from international frameworks such as Singapore’s ABC Waters Program and Australia’s Water Sensitive Urban Design (WSUD), they contextualize these models for Philippine application through proposed interventions like rain gardens, permeable pavements, and vegetated swales.

Based on the article of Frias and Maniquiz-Redillas (2021) entitled “Modelling the applicability of Low Impact Development (LID) technologies in a university campus in the Philippines using Storm Water Management Model (SWMM)” as a result of urbanization and rapid land development there is an increase of surface impermeability, affecting the natural hydrological cycle and resulting to excessive surface runoff, peak flows, and impacts on water quality. In the Philippines, urban areas development, specifically in highly populated cities, worsens these challenges, resulting in urban flooding, water supply insufficiency, and deterioration of environment. Traditional drainage systems primarily address channeling water faster but commonly provide insufficient attention to the quality of water or practices for sustainable management. To address these issues, Low Impact Development (LID) strategies have been developed as an effective approach, with the objective of managing stormwater at its source and imitating natural hydrological conditions.

Additionally, this study conducted at De La Salle University - Laguna Campus analyzed the effectiveness of eight LID strategies such as bioretention cells, infiltration trenches, rain gardens, green roofs, permeable pavements, rain barrels, rooftop disconnection, and vegetative swales by the use of Stormwater Management Model (SWMM). GIS-based delineation was used to subdivide the campus into three sub catchments, while classified rainfall data from 1989–2018 was applied to simulate different rainfall percentiles (80th, 90th, and 95th. The results presented that bioretention cells were most effective in lessening runoff under 80th percentile rainfall, while infiltration trenches enhanced infiltration under 95th percentile rainfall. In the first sub catchment surface runoff was reduced by more than 80% using several LID technologies, and larger sub catchments were beneficially correlated with runoff reduction but adversely correlated with infiltration.

Furthermore, the use of LID strategies can efficiently mitigate the adverse hydrological effects of urbanization through reduction of surface runoff, increased infiltration and water quality. Implementing the LID strategies can improve land use in developing cities, supports sustainable water management and resilient urban planning. The findings of this study are important references for future research to help policymakers and city planners incorporate LID strategies to enhance cities and communities sustainability.

According to Domingo et al. (2021) from the study, "Review of Urban Wastewater Management and Clean Water Act", a comprehensive evaluation of the status and challenges of urban wastewater management in the Philippines, framed

within the implementation context of the Clean Water Act (RA 9275). The paper addresses critical issues such as inadequate sanitation, low sewerage coverage (only about 5% of the population connected), and widespread improper disposal of industrial and domestic wastewater, which contribute significantly to environmental degradation and public health risks.

Additionally, this review focuses on the effectiveness of key policies and programs, particularly the National Sewerage and Septage Management Program (NSSMP), which aims to enhance sewerage infrastructure and services primarily in highly urbanized areas. Despite policy efforts, the study finds persistent gaps in implementation, regulatory enforcement, and infrastructure funding. The process evaluation framework employed reveals strengths in the collaborative governance approach but highlights weaknesses in nationwide coverage and resource allocation.

Moreover, the study emphasizes the need for policy augmentations to improve compliance with the Clean Water Act, strengthen local capacities for wastewater treatment operation and maintenance, and foster integrated urban water management that includes innovative decentralized sanitation solutions. The authors advocate for more inclusive, multi-stakeholder participation and increased government support to expand and sustain wastewater services, ultimately to protect water resources and public health in urban centers.

**Foreign Studies**

Several international studies have explored the relationship between community demographics and the acceptance of LID systems. Zhang and Chui (2018) surveyed residents in Hong Kong and discovered that individuals who had lived longer in flood-prone communities were more willing to adopt Low Impact Development (LID) solutions due to repeated exposure to flooding. Similarly, Brown et al. (2014) found in Australia that age influenced openness toward stormwater interventions—while younger residents were more receptive to innovative LID structures, older individuals expressed concerns about long-term upkeep and safety.

In examining the characteristics and challenges of stormwater runoff in urban areas, Park et al. (2019) conducted an assessment in informal settlements in Seoul and identified that the combination of high impervious surface coverage, densely packed housing, and limited drainage infrastructure significantly accelerated surface runoff and contributed to frequent occurrences of localized flooding. Their study highlighted that, in areas where natural infiltration was almost entirely obstructed by concrete and asphalt, even moderate rainfall events quickly overwhelmed existing drainage channels. Similarly, Lim and Lee (2017) observed in Singapore that conventional drainage systems were often rendered ineffective due to sediment accumulation, poor maintenance, and the absence of designated infiltration zones. They emphasized that reliance on centralized conveyance systems alone was insufficient for long-term flood mitigation, particularly in highly urbanized and rapidly developing districts. Consequently, both studies underscored the importance of adopting decentralized

stormwater management strategies, such as Low Impact Development (LID) retrofits, which promote infiltration, detention, and on-site water treatment. These interventions were found to not only alleviate peak runoff volumes but also enhance the resilience of vulnerable urban communities against climate-induced rainfall intensification.

Studies have also investigated which LID techniques are most suitable for dense or low-income urban environments, similar to communities in the Philippines. Li et al. (2019) evaluated rain gardens and bioswales in Beijing, concluding that bioswales were more effective in compact residential streets due to their narrow footprint and low construction requirements. Ahiablame and Shakya (2016) modeled LID adoption in flood-prone settlements in Ghana and recommended rain barrels and permeable pavements as cost-effective and community-friendly solutions adaptable to informal housing conditions.

Regarding cost-effectiveness and long-term maintenance, Moore and Hunt (2013) conducted a comprehensive analysis of bioretention systems in North Carolina and found that, although initial installation costs were sometimes perceived as higher than conventional drainage structures, the long-term economic benefits outweighed the upfront investment. Their findings showed that Low Impact Development (LID) facilities required minimal routine maintenance mostly limited to vegetation management and occasional sediment removal while offering 30–50% lower lifecycle costs compared to traditional stormwater conveyance systems. This reduction in cost was attributed to decreased reliance on extensive underground piping networks, lower energy consumption, and reduced need for large-scale infrastructure repairs.

Supporting this conclusion, Kong et al. (2019) evaluated the performance of permeable pavements in Malaysia and reported that maintenance activities, such as surface sweeping and clogging prevention, were manageable and could be effectively incorporated into existing municipal operations. They further noted that maintenance requirements could be significantly reduced through community participation initiatives, where local residents were engaged in simple upkeep tasks. This collaborative approach not only minimized operational costs but also promoted public awareness and stewardship over stormwater infrastructure. Collectively, these studies demonstrate that LID strategies present a financially sustainable alternative to conventional drainage systems, particularly in resource-constrained urban settlements.

The expected impact of LID systems on stormwater management has been widely validated through numerous performance evaluations across different climatic and urban contexts. Kim et al. (2020) conducted long-term monitoring of multiple LID installations in South Korea including rain gardens, swales, and permeable pavements, and reported a 25% increase in groundwater recharge, demonstrating the effectiveness of infiltration-based strategies in restoring natural hydrological cycles within urban environments. Additionally, their data indicated a 40% reduction in peak flow during heavy rainfall events, which significantly alleviated the burden on existing drainage infrastructure and reduced the frequency of localized flooding. Similarly, Smith and Johnson (2018) documented comparable results in California, where the application of permeable pavements in residential zones and public walkways yielded

consistent reductions in surface runoff volumes. Their findings also highlighted secondary benefits, such as improved surface cooling and enhanced pedestrian safety due to reduced standing water. These consistent outcomes across geographically distinct regions reinforce the reliability of LID measures as scalable and adaptable solutions for urban stormwater control. Furthermore, they underscore the potential of LID technologies not only to mitigate flood risks but also to contribute to long-term watershed sustainability and climate resilience.

**Local Studies**

The study conducted by Garbanzos and Maniquiz-Redillas (2022), " Evaluating the Peak Flow and Runoff Coefficient Reductions of Bioretention, Infiltration Trench, and Permeable Pavement LID Using Stormwater Management Model", focuses on assessing the peak flow and runoff coefficient reductions of LID controls using Stormwater Management Model (SWMM). Using three different LID controls (bioretention, infiltration trenches, and permeable pavements) and four rainfall scenarios (80th, 90th, 95th, and 99th rainfall percentile), evident reductions in peak flow and runoff coefficient have been observed. Larger reductions were observed in the 80% than in the other higher percentiles from the simulations. These reductions can reach up to 32 % in the peak flow and a 0.29 decrease in the runoff coefficient, where the high reduction values are found in the multiple LID scenarios. The widespread use of LID can help in mitigating these major stormwater impacts. It was also stated that LIDs work best at lower rainfall intensities, especially when the

combination of different types of strategies is used.

Furthermore, this study can guide the future creation and usage of stormwater systems, by using SWMM for performance checks, testing and simulations. LID can help address common stormwater problems in affected areas. In the Philippines, where LID is still being explored, these findings can support future efforts to apply, improve, and optimize LID solutions.

Based on the study of Boongaling et al. (2024) entitled "Assessment of low impact development (LID) strategies under different land uses in an urban sub-catchment in the Philippines" environment and society are greatly affected by the urbanization. A challenge includes polluted water resources, water quality degradation, groundwater reduction, biodiversity loss, and intensified flood-risks. These problems are notably significant in tropical urban areas, where fast-paced enhancement frequently surpasses the implementation of effective stormwater management systems. Urban areas are particularly prone to heavy rainfall because impervious surfaces limit soil infiltration and increase surface runoff.

Moreover, the traditional stormwater management systems frequently fail to address challenges of urban water management in tropical areas. Low Impact Development (LID) strategies have developed to imitate the natural water cycle, to specifically reduced runoff, enhanced infiltration and improved water quality. This study presents an application of different LID strategies implemented in a tropical catchment, and evaluates their performance in reducing peak flows, runoff volume management and flood mitigation. The research emphasizes the importance of

considering land use characteristics when designing and implementing LID solutions, such as soil type, vegetation cover, and surface impermeability because it can significantly influence their performance. Adapting specific LID strategies based on the environmental conditions of each land use type can also enhance the stormwater management systems application, reduce flood risks, and promote sustainable urban development. These findings can be used to conduct rapid assessments on LID selection and siting, provided similarities between land use characteristics described in this study and those at their localities are justified. This can lead to increased LID adoption towards building water-resilient and sustainable cities.

According to the study of Edra et al. (2023), "Analyzing the Effects of Low Impact Development Controls on the Hydrological Balance of a Highly Impervious Catchment Using Stormwater Management Model (SWMM)", the continuous expansion of impervious surfaces in developing areas poses a threat to the natural hydrological cycle and water balance. Impervious surfaces prevent rainwater to naturally soak into the ground and gradually seep into streams, and rather, the precipitation builds up and quickly enters storm drains. To address these challenges, low impact development (LID) technologies have been implemented in urban areas as they can replicate the conditions of undeveloped land in constructed environments

Additionally, this research used the Storm Water Management Model (SWMM) to examine the effects of LID strategies effect on the water balance in a highly impervious watershed. Using rainfall data characteristic of tropical climates, the study investigated permeable pavements, rooftop disconnections, and infiltration

trenches in two sub-catchments throughout four development phases. In regions with a lot of hard surfaces, these LID strategies can greatly increase infiltration and lower runoff. Among the strategies tested, the permeable pavements outperformed all other evaluated solutions, lowering runoff by up to 90% and boosting infiltration by up to 64%. However, there were also significant benefits when rooftop disconnection and infiltration trenches were combined, as infiltration increased by 13% and runoff decreased by 46%. Using LID strategies can help to restore the water cycle to a natural state like conditions and reduce the negative impacts of urbanization.

Moreover, in this study the potential of LID is explored and encouraged its usage in countries for managing stormwater. It highlights how LID measures affect the watershed's hydrological balance, which is important for successful implementation. The future researches on the added benefits and impacts of LID could help engineers and designers develop better plans for projects and actual construction, as well as having more data accuracy and validation.

In a study by Calot et al. (2022), entitled "Sustainable Drainage System: Low Impact Development Practices to Minimize the Storm Water Runoff", it explores the integration of Low Impact Development (LID) principles into urban drainage design to mitigate flooding and manage stormwater sustainably. Using modeling tools, the study compares traditional urban drainage approaches with LID-based strategies that focus on distributed control measures such as detention ponds, retention basins, infiltration trenches, and permeable pavements, integrated within the urban landscape.

Furthermore, by enhancing infiltration and delaying runoff, LIDs can help

restore natural hydrological conditions while lowering peak flood flow. The study shows that, particularly in plain watersheds, on-site control measures are more cost-effective than end-of-pipe systems, with cost reductions from 25% to 80%. Thereby, these measures contribute multifunctionally to the urban environment by integrating with green spaces and enhancing urban aesthetics.

Thus, applying LID strategies creates a sustainable urban drainage system by balancing urban growth and flood control, ultimately contributing to groundwater recharge and mitigation of flood risks. The study's findings support sustainable urban development approaches that prioritize natural flow conditions and encourage multifunctional drainage solutions over conventional centralized systems.

In a study conducted by Frias (2021), titled "Investigation on the applicability of low impact development in DLSU Laguna Campus using stormwater management model" evaluates the potential of Low Impact Development (LID) techniques to manage stormwater in the De La Salle University (DLSU) Laguna Campus area. Utilizing the Stormwater Management Model (SWMM), the study formulates 810 scenarios combining different subcatchments, rainfall intensities (60th to 95th percentiles), and eight LID technologies including bioretention cells, infiltration trenches, rain gardens, green roofs, permeable pavements, rain barrels, rooftop disconnection, and vegetative swales.

Key findings reveal that LID practices can reduce runoff by 12% to 80% and increase infiltration by 0% to 55% depending on the LID technology and scenario applied. Rainfall intensity and imperviousness level were positively correlated with

total runoff and negatively correlated with infiltration. Among the LID controls, infiltration trenches showed the most effective performance in runoff reduction, infiltration improvement, and green-gray ratio (ratio of pervious to impervious areas). The study also found that an optimal green-gray ratio of around 11:5 exists, beyond which increasing green space yields minimal additional runoff reduction or infiltration gains.

This research provides valuable guidance for adapting LID measures in developing urban contexts like the Philippines, aligning with sustainable development goals by promoting adaptive, green urban stormwater management. It serves as a useful reference for future LID implementation planning and policy formulation in the country's water sector

**Synthesis of Review of Related Literature and Studies**

Rapid urbanization, climate change, and increased impervious surfaces, remains a major challenge globally and in the Philippines that causes flooding, water pollution and environmental degradation. Recent studies emphasize the shift toward Low Impact Development (LID) as a sustainable, nature-based approach to stormwater management. Techniques such as rain gardens, permeable pavements, bioswales, and green roofs help reduce runoff, enhance infiltration, and improve water quality. Both foreign and local research confirm LID’s effectiveness in reducing peak flows, promoting groundwater recharge, and offering ecological and social benefits. However, policy gaps, limited technical knowledge, and community involvement

remain key challenges.

It is important to integrate urban planning, combining technical infrastructure with environmental and social considerations to develop resilient and sustainable cities. The use of SWMM or Stormwater Management Model is also an essential factor in integrating LID strategies to create simulations that can effectively show the relationship between surface runoff and LID strategies. Future urban water management must balance the development needs and the adoption of green infrastructure to mitigate flood risks, protect water resources, and enhance overall urban livability.

# CHAPTER 3

## Research Methodology

This chapter focuses on a detailed discussion of the methodology used in the study. It presents the research design method, the respondents of the study, the instruments used, data-gathering procedures, and the statistical treatment of data.

### Research Design

The researchers used a descriptive-quantitative research design in conducting the study. This design was used to gather an in-depth understanding of the established stormwater management systems in Purok 4, Phase 6, Barangay 178, Camarin, Caloocan City. The descriptive-quantitative method provides a detailed presentation of the current situation through numerical data and statistical analysis while providing an objective presentation of existing conditions without manipulating variables. By focusing on the collection and analysis of quantifiable information from actual observations and data collection, the study aimed to describe the present conditions and assess the sustainability of implementing Low Impact Development (LID) strategies in Purok 4, Phase 6, Barangay 178, Camarin, Caloocan City.

**Sample and Population**

In this study, the estimated number of 100 respondents from 70 households residing in Purok 4, Phase 6, Barangay 178, Camarin, Caloocan City, who experienced flooding in their area are the target population. The respondents were selected based on factors such as length of their residency, flooding experience in the area, and willingness to participate.

The sampling technique used in this study was purposive to gather relevant information from residents who are directly affected by stormwater issues in the area. This sampling technique was chosen to ensure the accuracy and relevance of the data. It enables the researchers to gather valuable insights for the design and assessment of Low Impact Development (LID) stormwater management practices suitable in the area.

**Research Instrument**

The researchers used a structured questionnaire as the main instrument to collect the data for the study. We created the questionnaire based on the research objectives so that we could get the right information from our respondents. It included Likert-scale items to measure the community's awareness, perception, and acceptance of Low Impact Development (LID) practices. To support the technical aspect of the study, two software tools were also utilized. EPA SWMM (Storm Water Management Model) was used to simulate stormwater runoff and assess the effectiveness of proposed LID strategies based on precipitation data from PAGASA. Meanwhile,

AutoCAD was used to create conceptual layouts and visual representations of the LID designs suitable for the study area.

To ensure validity, the instrument was reviewed and evaluated by subject matter experts and research panelists. After revisions and approval, printed copies of the questionnaire were prepared for distribution. We then printed the copies and allotted three to five days for their distribution in the selected area. The questionnaires were administered personally, and we provided brief explanations to the respondents before they answered.

**Data Gathering**

The researchers distributed the validated questionnaires to the target respondents within the selected community. Before the distribution, the purpose of the study was introduced, and the participants were assured that their responses would remain confidential and used only for academic purposes. Respondents answered the questions based on their knowledge, experiences, and observations related to stormwater, flooding, and environmental practices in their locality. During the data collection process, the researchers were present to address any clarifications needed by the participants.

In addition to the survey, secondary data on rainfall and precipitation were obtained from PAGASA. These data provided information on the rainfall patterns and intensity in the study area, which were used to support the assessment of suitable Low Impact Development (LID) stormwater management strategies.

After collecting the completed questionnaires, the researchers checked, counted, and organized the data. The answers were then encoded and arranged based on the frequency of each item. The collected data helped in figuring out the most suitable LID stormwater management strategies for the area.

**Statistical Treatment**

All collected data were subjected to statistical analysis to evaluate the hydrologic and water quality performance of the Low Impact Development (LID) stormwater management system.

**Percentage Formula.**

$$\mathbf{P = \frac{f}{n} \text{ x } 100\%}$$

Where:

- **P** = percentage
- **f** = frequency
- **n** = sample size

**Weighted Mean.**

$$\bar{X}_w = \frac{\sum f \times w}{N}$$

Where:

- **f** = frequency of responses
- **w** = weight

- **N** = total number of responses

**Percentage Reduction in Runoff and Peak flow**

$$\text{Reduction } (\%) = \frac{Q_{\text{before}} - Q_{\text{after}}}{Q_{\text{before}}} \times 100$$

Where:

- **$Q_{(before)}$** = runoff or flow rate before LID implementation
- **$Q_{(after)}$** = runoff or flow rate after LID implementation.